"Double (Antidrome) Conduction in the Central Nervous System." By C. S. SHERRINGTON, M.A., M.D., F.R.S., Holt Professor of Physiology, University College, Liverpool. Received February 15,—Read April 8, 1897.

In a paper presented to the Society last year,* I drew attention to some striking instances of "long conduction" through the bulbospinal cord, and among others to the following singular one. If after transection over the bulbospinal axis the *funiculus gracilis* be excited, *e.g.*, at the *calamus scriptorius*, the excitation evokes movement (contraction, relaxation) in the idiolateral hind limb. If instead of *f. gracilis* the *funiculus cuneatus* be excited the movement (contraction, relaxation) is in the idiolateral forelimb. The movement in the hind limb is in the monkey usually adduction and flexion of hallux, in the cat flexion of knee, hip, or ankle. In the monkey the forelimb movement is usually flexion and adduction of pollex, often with extension of the other digits; in the cat, more usually flexion of elbow with protraction of the shoulder. The movements which occur are, however, various, and I will here only add that those from the *f. gracilis* include the vaginal and anal orifices, the tail, and the abdominal muscles, those from *f. cuneatus* the diaphragm; but that neither from *f. gracilis* nor *f. cuneatus* have I obtained idiolateral extension of elbow or of knee.

In my former paper this phenomenon was recorded under the head of "long bulbo-spinal conductions." I did not offer any explanation of it, for it appeared to particularly require further investigation. I have, since communicating the above paper, taken various opportunities of examining the reaction further. My enquiry has elicited the subjoined results.

The movements evoked in the perineum or hind limb by excitation of the *f. gracilis* after transection of the bulb are obtainable from that column, after its isolation, by freeing it above and from its ventrolateral connexions for a length of 3 cm., and then suspending its upper end from a thread. The reaction is therefore hardly due to escape of the stimulating currents used, so that they reach the lateral columns and the descending tracts there contained. The currents employed have been induced, and of an intensity imperceptible, or barely perceptible to the tongue tip. The electrodes have been bright steel needles, placed about 1 mm. apart, and laid on the surfaces of the cord or bulb.

* "Experiments in examination of the Peripheral Distribution of the Fibres of the Posterior Roots of some Spinal Nerves, Part II," Abstract, 'Roy. Soc. Proc.,' vol. 60, No. 365.

The reaction is obtainable when the transection has been made altogether below the *nuclei graciles et cuneati*. It therefore does not necessarily involve the cells of those nuclei.

The reaction is not prevented by complete bilateral transverse severance of the ventro-lateral columns and grey matter of the cord at the—

5th cervical root level,
nor at the 8th „ „
„ 5th thoracic „
„ 1st lumbar „
„ 5th „ „ (cat).

The reaction is at once annulled on severance of the dorsal columns at any one of the above levels, although at the same time the ventro-lateral columns and the grey matter remain intact.

The reaction from the left *f. gracilis* is annulled by severance of the left dorsal column, that of the right by the severance of the right.

The reaction can almost always be obtained—although incompletely—by mechanical excitation, *e.g.*, by compression with ivory forceps, often even by a mere touching with the forceps.

That the conduction involved in the reaction does not implicate the fibres of the pyramidal tract—which at first instance suggest themselves as a source of fallacy—seems clear in light of the above. That supposition is also, and I think finally, excluded by the following observation. I have found the "long intra-spinal reflexes," like sub-cerebral rigidity ("decerebrate tonus,"*) locally abolished, or greatly depressed by total severance of the sensory spinal roots belonging to their own region of terminal discharge. Thus, to take an instance given in my former paper, if the right forepaw be stimulated the paths of "short spinal conduction"* from it lead to discharge of its own flexors of elbow, extensors of wrist, &c., as specified in the paper; and the paths of "long spinal conduction" from it lead to discharge of the muscles of the *idiolateral* hind limb. To evoke from the forepaw movement of the contralateral hind limb is relatively difficult; this contralateral movement is less commonly and less easily obtained, and when obtained less vigorous, less prolonged, and usually commences later than the idiolateral. But if, in the instance taken, the series of afferent spinal roots belonging to the right hind limb be severed, and stimulation of the forepaw (right) be then repeated, the movement induced in the hind limbs is contralateral, *i.e.*, a *crossed* one. In the

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idiolateral limb it is extremely difficult, often impossible, to then obtain by this facile long spinal path any discharge at all on the side of the transected afferent roots, although that side is usually peculiarly accessible. I find that similarly severance of the dorsal (afferent) roots in their extraspinal course greatly impairs the reaction from the *f. graciles* and *f. cuneati*. Thus, if when flexion of right knee or right hallux is being regularly evoked by excitation of *f. gracilis* at the top of the cord, the extraspinal dorsal (afferent) roots of the right pelvic limb be severed, the reaction, until then regularly obtained, disappears or almost disappears. The section of right hand roots annuls the right hand reaction, but not the left hand, and conversely. On the other hand, the flexion of knee, or of hallux, or of elbow obtained by excitation of the Rolandic cortex or of the lateral column (pyramidal tract fibres) is, as has been shown in a previous number of these 'Proceedings'* by Dr. Mott and myself, not impaired after the root severance, indeed often appears, on the contrary, to be facilitated. In this respect, therefore, the reaction obtainable by direct excitation of *f. graciles* and *f. cuneati* is shown to be curiously different from that obtainable from the pyramidal tract fibres and Rolandic cortex. On the other hand, it is seen to resemble in this respect to a remarkable degree the "long spinal reflexes" as defined above.

What, then, is the nature of this reaction obtainable from the *f. graciles* and *cuneati?* The reaction is evidently one which involves each dorsal column of the cord as a conducting path, in many cases as a "long"—in not a few as a remarkably long—conducting path, even employing its whole length. In light of the evidence given above, I infer that although certainly, as has been long established, the dorsal column is, with the single exception of its short, scanty, and deeply placed ground-bundle, a functionally purely *upward* path, consisting of nothing else than sensory root fibres, the vast majority of which fibres—and all the longest of which—are ascendant; the conduction along it in these experiments is *downward*, even extending its whole length. That is to say, the conduction must be downward and cellulipetal along ascending axons which function in a cellulifugal direction; that is to say, the propagation of the impulses artificially started in my observations must have been *antidrome* instead of *orthodrome*. The motor discharges evoked I refer to the spread of the excited condition into the collaterals of the axons excited to antidrome conduction, their collaterals impinging upon motor neurons.

The direction of propagation occurs therefore in opposition to the

* "Experiments upon the Influence of Sensory Nerves upon Movement and Nutrition of the Limbs," 'Roy. Soc. Proc.,' vol. 57, March 7, 1895.

law of the "*polarisation dynamique des nevrons*" put forward by Ramon-y-Cajal* and V. Gehuchten.† It offers, however, no contradiction to what James‡ has termed "the law of forward direction;" it only emphasises that that law predicates the existence of at least two links in its conduction-gear.

The reaction is therefore in my view an extreme illustration of double (antidrome, *doppelsinnige*) nervous conduction. After du Bois' fundamental observation with frog's sciatic and the electrical sign, it has been Kühne's *sartorius* experiment,§ and Babuchin's‖ reversed discharge in the electric organ nerve-fibre, which have laid a satisfactory foundation for double conduction in peripheral nerves. But between those experiments and these, the subject of this note, there are, it is true, differences. In the latter, (α) propagation occurs over relatively huge distances and (β) the reaction occurs within the field of the central nervous system. These differences need not, however, negative the relationship of the phenomena. They render it the more instructive.

It is obvious that there must be opportunity for detection of antidrome conduction in parts of the central nervous system besides the dorsal spinal columns. Thus, on exciting, especially with electric currents, the mammalian metencephalon (*vermis cerebelli*) and *isthmus rhombencephali*,¶ subsequent to ablation of the parts above, I have seen movements produced in the limbs and trunk, and also inhibitions occur. Thus, in instance of the latter, inhibition of the tonic extensor spasm of the fore and hind limbs combined with contraction of the flexors of knee and elbow, such as is seen under local spinal reflex action.** It will have to be determined whether in such cases as the former we have not before us instances of antidrome conduction along ascending paths. The antidrome phenomenon, while of valuable assistance when recognised, may, if unrecognised, give rise to very misleading inferences. Its methodic use should place in our hands a fresh instrument of value for neurological research.

* 'Medicina practica,' 1889; 'Revista de Ciencias Medicas de Barcelona,' Nos. 21 and 22, 1891.

† 'La Cellule,' vol. 7, p. 101, 1891.

‡ 'Psychology,' and *cf.* Waller, 'Science Progress,' vol. 3, p. 186, May, 1895.

§ 'Arch. f. Anat. u. Physiol.,' 1859, p. 595.

‖ Du Bois-Reymond's 'Arch. f. Physiol.,' 1877, p. 66.

¶ Sherrington, 'Roy. Soc. Proc.,' vol. 60, p. 414.

** Sherrington, *ibid.*